REMARKS

Acceptance/formal entry of the formal revisions being made to the Specification as well as reconsideration and withdrawal of the standing final rejection and allowance of the above-identified application is respectfully requested.

Amendments of a minor formal nature were effected in the Specification. Among the changes implemented are several revisions to correct discovered informalities. Additionally, minor editorial revisions were implemented for purposes of improving the readability thereof. It is submitted, these changes are strictly of a minor formal nature and, therefore, acceptance/formal entry is respectfully requested.

The following includes discussion/rebuttal arguments in support of patentability of the invention according to claims 3 and 4, etc. It will be shown below that the invention according to claims 3 and 4 could not have been rendered obvious over the combined teachings of Yamazaki, et al. (U.S. Patent No. 5,893,730) and Mitlitsky, et al. (U.S. Patent No. 5,714,404), as alleged in the outstanding rejection under 35 U.S.C. 103(a). Accordingly, this rejection is traversed and reconsideration and withdrawal of the same is respectfully requested.

A key aspect of the semiconductor device comprising plural transistors formed in the polycrystalline semiconductor thin film according to independent claim 3 and, therefore, according to dependent claim 4 thereof, concerns the improved polycrystalline semiconductor thin film structure. In this regard, base claim 3 specifies:

> "wherein the polycrystalline semiconductor thin film is formed by a plurality of laser irradiation steps, wherein the laser irradiation steps are carried out so that, after the last laser irradiation step, the number of

> crystal grains with the number of closest crystal grains of 6 is greatest among plural crystal grains that form the polycrystalline semiconductor thin film."

An example of such crystal grain formation in the polycrystalline semiconductor thin film is shown in Fig. 9(b) of the drawings (see also Fig. 5 as well as Fig. 8(b)). With regard to Fig. 9(b), for a central optional crystal grain 251, the number of closest crystal grains thereto is 6.

The structural aspects of the polycrystalline semiconductor thin film, according to the invention, are realized through implementing repeated laser irradiation steps such that after the last laser irradiation step, an improved polycrystalline semiconductor thin film structure with superior characteristics is realized, i.e., a polycrystalline semiconductor film in which the crystal grains thereof with the number of closest crystal grains of numeral 6 represents the largest lot of the same type of crystal grains that form the polycrystalline semiconductor thin film. That is, the inventors realized, that by implementing plural laser irradiation steps so that the shapes of the crystal grains are further transformed, for example, from an arrangement shown in Fig. 9(a) to the final structural arrangement shown in Fig. 9(b), a polycrystalline semiconductor thin film structure with superior characteristics is realized. It should be noted that the desired product shown in Fig. 9(b), for example, is only formed after plural laser irradiation steps are completed (see page 22, line 7-22, of the Specification).

An example of an improved polycrystalline semiconductor thin film structure in connection with the formation of transistors such as TFT(s) is described with regard to embodiment 1 of the present application, although not limited thereto. With regard to this the laser beam irradiation is implemented in two steps including a first excimer

laser irradiation (e.g. 604) and followed by a second excimer laser irradiation (e.g. 605) (see page 24, line 17 et seq. and Figs. 2, 10 and 11). In this example embodiment, 50 to 100% of the crystal grains 250 of the polycrystalline semiconductor thin film comprise hexagonal crystal grains 251 (see page 25, line 6 et seq. of the Specification). Such a polycrystalline semiconductor thin film structure leads to, for example, an improvement in the carrier mobility and, also, with regard to the reliability of the formed transistors (page 25, second and third paragraphs thereof, in the Specification). Also regarding the improved polycrystalline semiconductor thin film of the present invention, in which the laser beam is irradiated repeatedly, roughness on the surface of the polycrystalline semiconductor thin film is reduced and a planar polycrystalline semiconductor thin film substrate results. Such is realized when the roughness is kept to 5 nm or less. This is covered in dependent claim 4, etc. and an example discussion thereof is given on page 25, line 21, to page 26, line 16, of the present Specification. It is submitted claims 3 and 4, etc. define over the combined teachings of Yamazaki, et al. ('730) and Mitlitsky, et al., as applied in the outstanding rejection.

According to the rejection, Yamazaki, et al.'s schemed laser radiation, allegedly, may lead to the formation of monocrystalline film (i.e., single crystal) but that such laser irradiation does <u>not</u> lead to the formation of a hexagonal shape, for example, such as would occur in connection with a schemed construction of a polycrystalline semiconductor thin film according to base claim 3, which specifies:

> "wherein the laser irradiation steps are carried out so that, after the last laser irradiation step, the number of crystal grains with the number of closest crystal grains of 6 is greatest among plural crystal grains ttat form the polycrystalline... thin film."

However, it is alleged (in the rejection) that according to Mitlitsky, et al., "lasers may be used to form polycrystalline thin films at lower temperatures than conventional heating techniques." In this regard the discussion in column 10, lines 10-20, in Mitlitsky, et al. is specifically cited in the rejection. However, this citation of column and line numbers appears to be an error, noting that the description covers only four and one half columns and the entire patent to Mitlitsky, et al. contains only six columns. On the basis of Mitlitsky, et al.'s teachings, it is alleged that "*it would have been obvious... to modify Yamazaki [et al.'s] teachings to use a laser, rather than conventional heating, to form a polysilicon layer... because [,] as Mitilitsky [et al.] teaches, laser annealing prevents damage to underlying silicon substrates and still produces a multi-grained crystalline film (Col. 1, lines: 10-25).*" In other words, it is alleged that polycrystalline thin film, according to Mitlitsky, et al., could be formed at a lower temperature using a laser heating process because laser was used for forming a polycrystalline thin film at a lower temperature than a conventional annealing process. On this basis, it is alleged that the invention according to claims 3 and 4 are considered unpatentable over the combined teachings of Yamazaki, et al. and Mitlitsky, et al.

It is an objective of Yamazaki, et al. to form a monocrystalline thin film on a insulated substrate. In other words, it is an aim of Yamazaki, et al. to make a crystal structure such as of a silicon semiconductor thin film characteristically a single crystal and to use a single crystalline area to form the active region of the semiconductor device. The means by which Yamazaki, et al. intend to achieve this is given in connection with Figs. 1A – 1F and the discussion in column 7, lines 1-64 thereof. The crystal growth technique employed by Yamazaki, et al. ('730) is

extensively discussed in the remarks of the earlier submitted Amendment, which is also incorporated herein for purposes of this response.

Regarding the forming of the monocrystalline thin film and insulated substrate, according to Yamazaki, et al., it can be said that it is possible to form a thin film scarcely having a crystal grain boundary but can approximate that of a single crystal by forming a seed crystal having a high quality through growth of the solid phase and then attaining crystal growth through laser heating. In accordance with known crystal growth technology, the formation of a single crystal requires the following steps: forming of the crystal core, growth of the core crystal and growth of the crystal. Likewise, Yamazaki, et al.'s scheme also depends on such principle and, in fact, uses Ni as a catalyst. In Yamazaki, et al., the formation of the crystal core and multi-crystal grains is realized through employing a solid phase growing technology and, further, to achieve crystal growth, additional laser heating leads to improved crystallization through liquid phase growth.

Yamazaki, et al., it is submitted, employs a completely different technique then the laser irradiation steps leading to the formation of the improved polycrystalline semiconductor thin film according to claims 3 and 4. <u>The structure shown in Fig. 2A in Yamazaki, et al., as was earlier shown, is a temporary structure which exists during the formation of a final product, which is the stripe-type large crystal grain product shown in Figs. 2B and 2C</u>. The hexagonal column-like crystal is a core crystal so that upon completion, there are realized stripe-like large crystalline grains each grown in a lateral direction.

An objective of Mitlitsky, et al. is to form a polycrystalline semiconductor film having a large crystal grain diameter on a light-weight substrate (that is fragile to

heat) in connection with improving efficiency of a solar cell. To achieve this, Mitlitsky, et al.'s scheme calls for the semiconductor film to be irradiated with a pulsed laser, in which the thin film becomes crystallized without any thermal damage to the substrate in connection with realizing crystal grain growth.

An objective of the present invention, however, is to restrict variation in performance of a thin film transistor (TFT) by using a polycrystalline semiconductor thin film in the formation thereof and whose structure is according to that set forth in clams 3 and 4, etc. In other words, a transistor such as a TFT according to the present invention uses a polycrystalline semiconductor thin film that is structured such that the largest lot of crystal grains is characterized by crystal grains with the number of the closet crystal grains thereto being 6. As described on page 7, lines 12-15, of the Specification, an objective of the present invention is to "provide a polycrystalline semiconductor thin film in which the size of the crystal grains and carrier concentration are uniform and which has a planar surface." The Examiner is also referred to the discussion on page 23, line 6 et seq. and line 19 et seq. as well as from page 24, line 17, to page 26, line 16, of the Specification such as it relates to example disclosed embodiment 1. It is submitted, it is not an objective of the present invention to produce a transistor with performance characteristics equivalent to that of single crystalline silicon material and structured with the same uniformity requirements of a transistor of a single crystalline Si type. That is, <u>the present invention, as set forth in claims 3 and 4, etc., is aimed at achieving an improved construction/performance associated with a polycrystalline semiconductor thin film</u>.

A reason why the present invention calls for using a polycrystalline semiconductor thin film in the formation of transistors of a semiconductor device is

because it is more convenient than that of a single crystal type, although its performance is inferior to that of the single crystal structure. That is the present invention, effectively, can eliminate a seed crystal forming process and attain direct grain growth. This fact advantageously contributes to an improvement in throughput and also leads to cost reduction in the manufacturing process. The showings in Fig. 6(a) – 6(c), which are based on the inventors' investigative findings (including experiments performed by them), contribute to achieving an improved polycrystalline thin film structure. The following are representative of the outcomes of experiments performed by the present inventors for producing high quality polycrystalline materials such as polycrystalline silicon material:

(1) The density of shape of crystal grain has a normal distribution (Fig. 6(a));

(2) A normal distribution having a hexagonal crystal grain of a high peak value indicates the narrowest half width value (In other words, the highest uniformity) (Fig. 6(b)); and

(3) There are present both a laser energy fluence Ec where most of the hexagonal crystal grains constituting the polycrystalline film are hexagonal crystal grains associated with six crystal grains closest thereto and the number of times of irradiation associated therewith is Mc (the optimal number of laser irradiation cycles is Mc when the laser beam irradiation is applied at the laser energy density of Ec or lower (see Figs. 6(c) and 7(a) and the discussion from page 18, line14 to page 20, line 20, of the Specification)).

In accordance with the inventors experimental findings, the suitable shape selection laser energy density Ec and the optimum number of laser irradiation cycles Mc should be determined for each condition of the amorphous silicon (Si) thin film since they are dependent on both (a) a process for forming an amorphous Si thin film before the irradiation of laser (e.g., a pressure reduced CVD or a plasma CVD process) and (b) a film thickness. It is generally understood, by the skilled artisan, that a condition of excimer laser irradiation depends on amorphous Si thin film. It is apparent, therefore, the means used in connection with achieving the present invention is quite different from that disclosed or suggested in view of Yamazaki, et al.'s and Mitlitsky, et al. In other words, it was the mentioned experimental findings by the present inventors which has led them to achieve an improved polycrystalline semiconductor thin film in connection with the formation of plural transistors in a semiconductor device as that according to claims 3 and 4, etc. It is submitted, such could not have been realizable from the combined teachings of Yamazaki, et al. ('730) and Mitlitsky, et al.

The following discussion concerns the origin of the expression "the number of closest crystal grain," which is used in the claims. An experiment was conducted (by the inventors) regarding crystallization of amorphous silicon thin film with an excimer laser irradiation with fluence of the excimer laser and a number of times as the perimeters. A thin film was evaluated in such a way that the grain boundary was visualized through a seco etching and photographed by a scanning electron microscope so as to analyze the photographs obtained. The gist of the analysis consisted of (a) measurement of respective crystal grain diameters and (b) measurement of how many grains adhere around one crystal grain. (This refers to

the number of closest crystal grains N). A reason why the shape of respective grains (pentagonal or hexagonal and the like) were not evaluated directly but that the number of closest crystal grain was evaluated is because the grain boundary for the polycrystalline thin film shown in the photograph taken by the actual scanning electron microscope is not necessarily linear. That is, both a linear grain boundary and a covered grain boundary were found to be present. If the grain boundary is constituted strictly as a linear grain boundary and the size of the grains were uniform, both a shape of an individual crystal grain and the number of proximity crystal grains would be equal to each other. However, the form of the structure of the actual polycrystalline thin film was not so defined as is noted above. In addition, as shown in Fig. 9(a) of the drawings, two crystal grains are contacting the same side of the crystal grain, in some cases. In consideration of this, the present inventors have come up with a method for measuring the number of closest crystal grain. However, since the expression of the proximity crystal grains is not a typically recognized expression, the present inventors, for the sake of convenience, have come up with an expression based on that used in the claims. Namely, the crystal grain having the number N of proximity crystal grains has been defined in the Specification as an N-polygonal crystal grain.

As can be seen from Fig. 9(a), an actual polycrystalline thin film may include many hexagonal grains but some of these grains have closest crystal grains which number 7, etc. The semiconductor device according to claims 3 and 4, etc. set forth an improved polycrystalline semiconductor thin film which includes many grains each being characterized as having closest crystal grains thereto numbering 6. In order to achieve this, the polycrystalline semiconductor thin film structure is defined as that

which results after the last laser irradiation step is performed. An example of this is the resulting crystal grain arrangement of the improved polycrystalline semiconductor thin film at completion of the second laser irradiation (see page 21, line 7 et seq. of the Specification and Fig. 8(b)).

It is submitted, for at least the above reasons, the invention according to claims 3 and 4, etc. could not have been rendered obvious even over the combined teachings of Yamazaki, et al. ('730) and Mitlitsky, et al.

Acceptance of the above made formal revisions to the Specification as well as withdrawal of the outstanding rejection and early allowance of the above-identified application is respectfully requested.

Claims 14-15, which are directed to a "method of manufacturing..." and which were previously withdrawn from purposes of examination, as a result of an election made without traverse, in connection with an earlier Restriction/Election Requirement, are being cancelled (without prejudice or disclaimer) so as to remove this other issue, at this time.

If the Examiner deems that questions and/or issues still remain which would prevent the present application from being allowed at the present time, she is invited to telephone the undersigned representative, at the telephone number indicated below, so that either a telephone or personal interview may be arranged at the Examiner's convenience in order to discuss the same and hopefully resolve any remaining questions/issues present.

To the extent necessary, Applicants petition for an extension of time under 37 CFR 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Antonelli, Terry, Stout & Kraus,

LLP Deposit Account No. 01-2135 (Docket No. 520.41003X00), and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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